SUMMARY OF TWO STUDIES PERFORMED BY

RUTGERS UNIVERSITY AGRICULTURAL EXPERIMENT STATION

STUDY I: ASSESSMENT OF SOIL DISTURBANCE ON FARMLAND

and

STUDY II: CHARACTERIZING THE MODERN NEW JERSEY FARM LANDSCAPE

April 23, 2010

On December 4, 2008, the State Agriculture Development Committee (SADC) authorized entering into a contract with Rutgers, the State University of New Jersey, New Jersey Agricultural Experiment Station Cooperative Extension (NJAES) to conduct two specific studies.

Study I: "Assessment of Soil Disturbance on Farmland". The first component of this study comprised a review of academic literature available on the topic of the impact of certain agricultural practices on the physical, chemical and biological properties of soil, and a resulting summary of findings. The second component entailed synthesizing that information into a format that identifies the relative impact of those practices on soil health, and the degree to which their impacts can be remediated.

Study II: "Characterizing the Modern New Jersey Farm Landscape" is an "on the ground" analysis of the nature and extent of agricultural infrastructure occurring on a variety of agricultural operations. The study involves the onsite investigation of 10 farms located throughout New Jersey.

The SADC established the Agricultural/Horticultural Development Subcommittee, later identified as the Deed of Easement Subcommittee, charged with the task of researching the effects of soil disturbance and construction of improvements on preserved farmland in order to help formulate the SADC's future policy direction on these issues.

Deed of Easement Subcommittee. The Subcommittee is comprised of the following members:

Farmer Members: Alan A. Danser
Stephen P. Dey, II., D.V.M.
Torrey Reade

Public Members: James R. Waltman
Denis C. Germano, Esq.

The Subcommittee held meetings on January 22, February 20, June 10, October 8, 2009, and November 12, of 2009, and January 12, February 17, March 11, and April 16,

2010, to evaluate findings and recommendations pertaining to the two studies in addition to considering other matters related to interpreting the Deed of Easement. During this process, the Subcommittee and SADC staff had consulted with representatives from the USDA, Natural Resources Conservation Service (NRCS), NJAES, New Jersey Department of Agriculture (NJDA) and the New Jersey Department of Environmental Protection (DEP_ to assess various perspectives, concerns and comments.

Following is a summary of the two NJAES studies.

Study I: Assessment of Soil Disturbance on Farmland

The initial report of Study I issued by the NJAES on December 22, 2008, provided a preliminary analysis of the issues and a compilation of the academic references that were available on the general topics of soil conservation, compaction and soil engineering.

The Subcommittee evaluated the initial findings of NJAES' Study I and Study II and recommended the SADC to proceed with completing the first phase of Study I to focus the remaining research to common agricultural practices that 1) deprive soil of normal exposure to the elements (i.e., various forms of impervious cover) and/or 2) result in compaction or disturbance of the soil, other than normal tillage practices. The disturbance aspect of the research was intended to focus on agricultural practices that require construction of buildings/structures that result in substantial soil disturbance.

The SADC authorized NJAES to proceed with the completion of Study I, giving specific direction to evaluate the following agricultural practices:

1. The use of geotextile fabrics placed over undisturbed soil which may or may not be covered with several inches of gravel;

2. Seasonal use of impervious cover (high tunnel hoop houses) where the soil is being used in its existing condition as the growth medium;

3. Long-term use of impervious cover where the material is kept on the structure for an extended period of time (a minimum of two years) where the soil is not used as the growth medium and the soil is generally covered with fabric with or without gravel;

4. Long-term impervious cover where the soil has been altered as a result of permanent structures requiring foundations and the flooring is covered with fabric, fabric with gravel or concrete;

5. Long-term impervious cover over undisturbed soil such as indoor riding arenas; and

6. Long-term impact of outdoor equine training tracks that either level areas or areas where the soil has been significantly graded.

A draft report was provided to the SADC on November 16, 2009, and a final report was submitted on April 5, 2010. The authors involved in the research and drafting of the report are as follows:

Dr. Daniel Gimenez, Associate Professor, Soil Science/Soil Physics, Department of Environmental Science
Daniel Kluchinski, County Agent (Professor) and Chair, Department of Agricultural and Resource Management Agents
Dr. Stephanie Murphy, Director, Soil Testing Laboratory, Instructor, Physical Properties of Soils, Soils and Water, Department of Environmental Science
Loren Muldowney, Lab Technician, Soil Testing Laboratory

The study addressed issues including soil conservation, soil quality and sustainability in agriculture, soil quality as influenced by management, compaction, attributes of compaction as a form of soil degradation, compaction as a continuum and research on compaction and remediation.

Due to the extensive nature of the topics studied, the literature search and final analysis was limited to research on humid, temperate zone agriculture which is similar to New Jersey conditions and soils. The report also qualified that in addition to the literature findings, the professional expertise and opinions and common professional knowledge of the authors formed the basis for the statements and recommendations provided. In addition, the findings and recommendations that were made did not consider the extent of disturbance or its purpose.

The report recognizes the classification of soils into Prime Soils, Soils of Statewide Importance, Soils of Local Importance and Unique Soils, which are recognized as important soils for agricultural production purposes. It further indicates that any practice or activity that degrades those soils into lower classifications makes them less suited to long-term agricultural sustainability and is contrary to soil conservation goals. Due to the varying nature of soils, remediation efforts will vary as well as length of time to achieve certain results.

The report then focuses on the influence of soil management practices on soil quality, and indicates that the soil properties considered most representative of the overall soil health or quality include: organic matter content, soil structure, bulk density, infiltration rate, and activity of the biological community. "Collectively, management will aggrade, sustain or degrade the quality of the soil."

Compaction: Compaction is considered the "most widespread kind of physical soil degradation across all soil textures".

The following major findings regarding the impacts of compaction were identified:

- The degree and depth of the disturbance by compaction influences whether a remedy is possible or feasible, or whether the damage is permanent.

- Compaction causes the following problems: soil structure is destroyed, plant growth is negatively affected, natural hydrology is circumvented and increased water runoff occurs.

- Compaction is not easily or rapidly remediated.

- Compaction often reaches the subsoil (12 to 20 inches or more)

- Subsoil compaction is a long-term and possibly unsolvable problem depending on the degree of compaction where recovery may require nine or more years, or the damage may be permanent. Compaction that extends beyond the topsoil into the subsoil may be beyond economically feasible remediation, depending on the depth of the damage. Subsoil compaction is normally considered permanent damage of agricultural land.

- The literature does not consider the effects on crop yields of compaction for engineering purposes since the context and intent of such compaction is a permanent conversion of a soil growth medium to a soil as an engineering medium. (Note: Compaction for engineering purposes is for the purpose of establishing a stabilized base to construct a building. Therefore, the literature does not address its ability to be utilized for agricultural purposes.)

- No research literature was found on the subject of site remediation following intentional compaction for engineering/construction purposes. It is assumed that such compaction is a permanent change to the soil and such soil results in creation of a nearly impermeable surface or layer.

- In agricultural enterprises, the acreage that is converted to be an “engineering medium” should be minimized if the objective is to maintain as much farmland as possible in a productive and quality state.

- Land reclamation following surface mining may provide a good indication of the magnitude of the restoration required following compaction for structural engineering purposes. While it may be technically possible, it is not considered feasible given any reasonable level of expected economic return.

- Compaction is not always recognized by the land user as a source of yield reduction. Typically, management is modified to compensate for whatever is limiting to production; e.g., increased energy use, more frequent field operations and higher fertilizer and water use.

Specific Farm Practices:

? Leveling that does not reduce the thickness of the topsoil could be a relatively benign operation if used to increase water infiltration to reduce overland flow.

? Tillage is generally accepted as a routine and acceptable agricultural practice. However, tillage usually results in some degradation of soil quality because it breaks down soil structure, compacts soil and decreases certain populations of soil organisms. However, this must be balanced with the necessity of tilling the soil to prepare the soil for the crop.

The following findings were made with respect to the specific agriculture infrastructure practices the SADC identified to be studied:

? **Geotextiles**: Little if any information is available regarding their effects on properties underlying the soil. The degree of related soil disturbance and not necessarily the geotextile material is what determines the effect on soil disturbance. Due to the lack of literature, the authors determined that based on general soil science, geotextiles used as a weed-blocking cover over undisturbed soils may lead to a gradual reduction in soil organic matter. It can be expected that the resulting reduction in soil quality can be remediated by removing the geotextile and growing a soil-building cover crop and proper management to restore the loss.

? **Seasonal use of impervious cover over undisturbed soil where the soil is being used in its existing condition as a growth medium (high tunnel hoop houses)**: The use of high tunnel hoop houses is increasing throughout the country to extend the growing seasons during the fall and spring months. The construction does not involve the compaction or excavation of soil unlike permanent greenhouses. Wood framing is used as a base to which PVC tubes driven into the ground and looped to the opposite side of the structure are covered with a polyethylene greenhouse covering. Based on the professional judgment of the authors, the main impact will be the limitation of precipitation infiltrating and passing through the soil. The increased soil temperatures may be sufficient to increase soil biological activity, which may enhance nutrient availability but decrease oxidation and loss of soil organic matter. Stormwater management may be necessary to handle excess water runoff. Steps to remediate any negative impact on soil properties are minimal and the return to traditional agricultural production can be easily achieved. Management practices to introduce organic matter into the soil will remediate the loss of organic matter.

? **Long-term use of impervious cover (high tunnel hoop houses for two years or more)**: The Rutgers analysis considers the limitations somewhere between the "Seasonal use of impervious cover over undisturbed soil where the soil is being used in its existing condition as a growth medium (high tunnel hoop houses)" and "Long term impervious cover (roof) over undisturbed soil."

- **Long-term impervious cover (roof) over undisturbed soil**: Based on the professional judgment of the authors and literature research, the amount and quality of sunlight, and the amount and quality of water passing through the soil, are the main limitations. Depending on the type of roof material, light limitation will affect plant growth and, therefore, organic matter addition and microbiological population and activity in the soil. Elimination of natural precipitation from soil may or may not have an effect depending on other management factors. Routine application of fertilizer without leaching/water can lead to salt build-up (salinity), another form of soil degradation. Remediation steps would include the reintroduction of organic materials to increase soil aggregation and other physical properties and biological activity. Rainfall and irrigation, and use of soil amendments such as gypsum, would help to leach any accumulating salts over time, most likely several months to a year or two depending on the soil conditions.

- **Permanent structure and long-term impervious cover with soil substantially disturbed (including geotextile alone, geotextile with gravel cover or concrete foundation)**: When the soil is strictly an engineering medium, soil compaction is necessary to provide a stable base for a permanent structure. This activity is contrary to soil conservation practices. Soil structure is destroyed or soil is removed to establish a stable base. The impervious nature of the soil impedes water from infiltrating, filtering and passing through the profile to groundwater, therefore, stormwater runoff would be increased. Geotextiles with gravel cover could mitigate the negative effects, but concrete foundation "seals" the fate of the entombed soil. A new soil classification is being developed for urban soils that includes "Technosols" whose development and properties are dominated by their extensive disturbance by man. A soil sealed by concrete would be considered a Technosol. Remediation under these conditions would be more difficult and costly. Upon removal of the structure, yields in the disturbed areas would be expected to be less than similar undisturbed soils. The primary impacts would be that the majority of the soils' inherent characteristics are negatively impacted and its profile would be permanently and negatively altered. The extent of soil disturbance should be limited or the purpose for it justified in a soil management plan.

- **Long-term impact of outdoor equine training tracks**: The construction of equine training tracks may involve grading (leveling and/or smoothing), compacting the soil base and layering with desirable footing material. Subsequent management includes tractor-mount raking and rolling to eliminate vegetation and to smooth and firm the surface. The effects on the underlying soil would include primarily compaction of the soil by both horse and tractor. Organic matter of the soil will be depleted as the original humus is oxidized. The surface of the non-vegetative track is likely to experience erosion by rain and wind. Remediation steps would include the reintroduction of organic materials to increase soil aggregation and other physical properties and biological activity.

The report included a "**Relative Impact of Practices on Selected Soil Functions and their Potential for Remediation**" based on the authors' professional judgment and experience. The classification ranging from "very high" to "very low" potential for remediation is as follows:

Practice	**Soil Functions**			**Potential for Remediation**
	Food and Biomass Production	**Storing, Filtering and Transformations**	**Biological Habitat and Gene Pool**	
Geotextiles	Very negative (no biomass production)	Limited reduction of biological activity and of exchanges of matter and energy with the atmosphere.		Medium to High
Impervious Cover-Seasonal	Enhanced (biomass production augmented)	Limited negative or neutral impact due to short time scale.		Very High
Permanent Structures	Very negative impact on all soil functions			Very Low
Outdoor Equine Training Tracks	Very negative impact on all soil functions			Low

The study team concluded the following:

1. Most minor to significant negative practices can be remedied through various cultural practices, however, increasing costs (time, money) may be prohibitive and reduction in crop yield or quality may be depressed for periods of time.

2. Soil under almost any condition can be improved, but there is potential for a loss of productivity if the soil structure has been irreparably harmed.

3. The determination of what is "acceptable" and "unacceptable" soil disturbance can only be established through research involving the set of practices under consideration and the soil and climate conditions in New Jersey.

Study II: "Characterizing the Modern New Jersey Farm Landscape"

The initial draft report of Study II issued by the NJAES on September 15, 2009, was reviewed by SADC staff and presented to the Subcommittee on October 8, 2009. The report was authored by the following:

Jack Rabin, Associate Director, New Jersey Agricultural Experiment Station
Rodger Jany, Program Assistant, Rutgers Cooperative Extension of Mercer Co.
Brian J. Schilling, Assistant Extension Specialist, Rutgers Cooperative Extension
Lucas J. Marxen, Research Analyst, Food Policy Institute

This report was instrumental in understanding the nature and extent of agricultural infrastructure that exists in support of agricultural business on a variety of types of farms. It also detailed the specific types of disturbance and impervious cover that helped focus the completion of Study I, Phase I, to be conducted by NJAES.

Note: *It should be understood that the farms selected were intentional for purposes of evaluating a wide range of agricultural operations as well as a wide range in agricultural infrastructure. NJAES staff, in conjunction with county agricultural agents, identified specific farm operations that were indicative of production agriculture and not "hobby farms." Some of the farms were enrolled in the Farmland Preservation Program and others were not. Due to federal requirements, NJAES was unable to disclose the name of specific farms where the owners did not sign a release to disclose that information*

The report provided a preliminary analysis of small sample of farming operations in New Jersey which typically consist of the "farm homestead," defined generally as the base of operations for the farm management unit, which may comprise other non-contiguous properties. As part of the farm homestead, the main area where structures are built and improvements have been made was identified as the "core complex" and delineated both in the office and on the ground. The "core complex" is an area where the agricultural infrastructure is generally concentrated within the farm homestead. However, there may be other modified uses on the farm that are not contained in the core complex area figures as identified in the study. The report identified the combined areas (core complex and other modified areas) as "modified uses."

New Jersey 2007-2008 high resolution orthophotography maps were obtained for each case farm. At the direction of the SADC, a total of 10 farms were evaluated. The farms included grain, vegetable/fruit, nursery, wholesale greenhouse and livestock operations.

The farm landscape modification categories were identified as follows:

1. Permanent Improvement – concrete floor
2. Permanent Improvement – dirt/gravel floor
3. Temporary/Moveable Improvement
4. Production Area - field, pasture, orchard
5. Equipment Movement Area – gravel/paved
6. Equipment Movement Area – dirt
7. Lawn or Buffer
8. Pond or Drainage
9. Appurtenant Land

In-the-field measurements were taken to delineate the above features and recorded for each farm. For purposes of the study, several landscape modifications were condensed into a "modified uses" category to reflect physical modifications that were made to the farm landscape to support agricultural production as follows:

1. Permanent improvement – concrete floor
2. Permanent improvement – dirt/gravel floor
3. Temporary/Moveable Improvement
4. Equipment Movement Area – gravel/paved
5. Pond or Drainage

The farms that were evaluated had "farm homestead" areas that ranged in size from 20 to 231 acres and had "modified uses" that ranged from 2.9 to 73.8 percent of the farm homestead. "Core complex" areas were identified as a subset of the area identified as "modified uses". An interesting finding of the study was that "built structures" referred to as "vertical improvements" generally comprised considerably less area than modifications associated with equipment movement areas, ponds or drainage referred to as "horizontal improvements."

The report provides a detailed analysis of each farm identifying the specific features occurring on each farm with an analysis of acreage and percent of the measured components. From the onset, it was realized that this report was not intended to be "representative" of the agricultural industry because of the small sample of farms being considered. Time and budgetary constraints were limiting factors. However, due to the manner in which the farms were selected and investigated, the data was very useful in understanding the varied infrastructure needs of New Jersey's diverse agricultural industry.

Furthermore, it was clear that the actual site visits provide more detailed information about the interior of structures such as the diversity in substrata ranging from exposed soil, soil covered with geotextile fabrics, geotextile fabrics covered with several inches of gravel and in some instances concrete walkways or complete concrete floors.

Areas within the core complex used as roadways, parking areas, storage areas, etc., also had a wide range of stabilization techniques, which varied from exposed (compacted) soil, gravel, blacktop and/or concrete.

The nature and extent of the types of agricultural structures were also quite varied. These structures ranged in size as well as permanency. Temporary structures, (hoop houses) were comprised of metal frames, covered with polyethylene and held together with wooden base boards. These structures were used in the nursery, vegetable and horticultural industries for providing a controlled environment for plant production. One form of the temporary hoop houses, known as "high tunnel" hoop houses, are temporary structures comprised of metal frames covered in polyethylene that are used to extend the growing season by allowing the farmer to start early in the season and/or to extend the end of the growing season. In these cases, the actual soil is used as the plant medium. In the case of high tunnels and some nursery applications, the polyethylene covering is removed at the end of the season. In other nursery and horticultural applications, the plastic material is kept in place indefinitely and provides a more permanent growing environment. Permanent structures consisting of permanent rooftops and foundations also varied with internal substrata ranging from exposed (compacted) soils to concrete floors and foundations.

The report was also originally intended to analyze the accuracy of measurements taken in-the-field as compared to measurements generated using the SADC's in-office Geographical Information System (GIS) tools. Unfortunately, given the confidential nature of the data collected by Rutgers, the SADC is not privy to the identity of the analyzed farms, therefore, we cannot compare Rutgers' measurements to SADC generated measurements.

A draft final report was submitted to the SADC on December 3, 2009, which prompted additional comments, and a final report was issued on March 5, 2010.